

**This Page Is Inserted by IFW Operations  
and is not a part of the Official Record**

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problems Mailbox.**

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



M

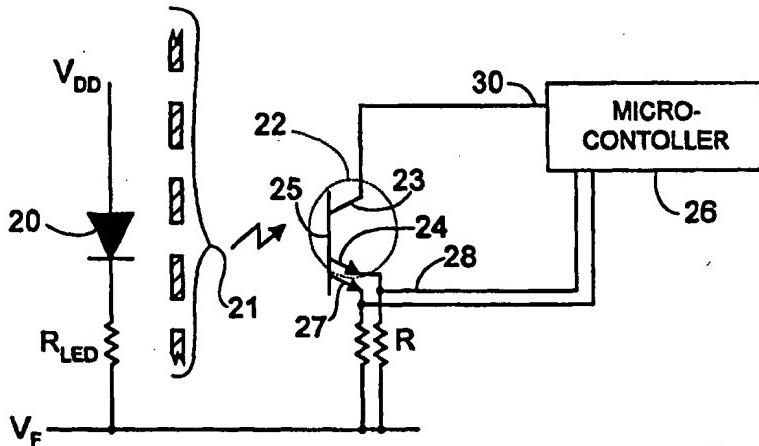
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> :	A1	(11) International Publication Number: WO 00/33245
G06K 11/18, H03K 17/795		(43) International Publication Date: 8 June 2000 (08.06.00)
(21) International Application Number:	PCT/US99/28129	(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date:	30 November 1999 (30.11.99)	
(30) Priority Data:	09/201,697 30 November 1998 (30.11.98) US	
(71) Applicant (for all designated States except US):	MICROSOFT CORPORATION [US/US]; One Microsoft Way, Building 4, Redmond, WA 98052-6399 (US).	
(72) Inventors; and		Published
(75) Inventors/Applicants (for US only):	FEATHERSTON, Lord, Nigel [US/US]; 15112 Old Redmond Road, Redmond, WA 98052 (US). MAURO, Charles, Salvatore, Jr. [US/US]; 21707 N.E. 203rd Street, Woodinville, WA 98072 (US). LEE, Mark, R. [US/US]; 330 N.W. 76th Street, Seattle, WA 98117 (US).	With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.
(74) Agent:	WIGHT, Stephen, A.; Klarquist, Sparkman, Campbell, Leigh & Whinston, LLP, Suite 1600, One World Trade Center, 121 SW Salmon Street, Portland, OR 97204 (US).	

(54) Title: APPARATUS AND METHOD FOR SAMPLING A PHOTOTRANSISTOR

(57) Abstract

Sampling of a phototransistor in an optical encoding system is controlled by "turning on" the phototransistor, after light has already charged the base of the phototransistor at least somewhat, by applying a potential difference across the collector and emitter of the phototransistor, producing an essentially instantaneous emitter response, which is then sampled.



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	MW	Malawi	TR	Turkey
BG	Bulgaria	HU	Hungary	MX	Mexico	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	NE	Niger	US	United States of America
CA	Canada	IT	Italy	NL	Netherlands	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NO	Norway	VN	Viet Nam
CG	Congo	KE	Kenya	NZ	New Zealand	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	PL	Poland	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PT	Portugal		
CM	Cameroon	KR	Republic of Korea	RO	Romania		
CN	China	KZ	Kazakhstan	RU	Russian Federation		
CU	Cuba	LC	Saint Lucia	SD	Sudan		
CZ	Czech Republic	LI	Liechtenstein	SE	Sweden		
DE	Germany	LK	Sri Lanka	SG	Singapore		
DK	Denmark	LR	Liberia				
EE	Estonia						

## APPARATUS AND METHOD FOR SAMPLING A PHOTOTRANSISTOR

### TECHNICAL FIELD

5        This invention relates to apparatus and methods for sampling the output of a phototransistor, particularly for optical encoding systems employing phototransistors in user input devices such as thumb-wheels, finger-wheels, mice, trackballs, and the like. More particularly, this invention relates to an opto-mechanical encoding system in which a potential difference is applied  
10      intermittently across the collector/emitter of a phototransistor to control sampling of the phototransistor output so as to provide an essentially immediate response representative of the light flux at the phototransistor. The apparatus and methods of this invention may also be applied to other transistors.

15

### BACKGROUND OF THE INVENTION

User input devices such as mice and trackballs for use with computers and other electronic devices commonly use opto-mechanical encoding to sense position and/or movement. Motion of the ball of a mouse or  
20      trackball, or motion of the wheel and/or shaft of a thumb- or finger-wheel, for example, typically rotates a pair of encoding wheels having light-transmitting and light-blocking regions

Each encoding wheel is typically positioned between one or two light sources in the form of LEDs (light emitting diodes) and two light sensors in the  
25      form of a PTRs (phototransistors). For each PTR, the surface area of the PTR exposed to the light from the LED(s) is directly correlated with the position of the encoding wheel, and may be approximately represented by a periodic function of the position of the encoding wheel. The signal voltage at the emitter

- of each PTR is, in typical configurations, directly proportional to the surface area of the PTR exposed to light. The light source(s) and the two PTRs are typically positioned, relative to each other and to the encoding wheel, such that the signal voltage from one PTR varies approximately in quadrature with the
- 5 signal voltage from the other PTR, as a function of the position of the encoding wheel. The signals from the two PTRs, taken together, are thus representative of the velocity and direction of motion of the encoding wheel: the frequency of the signals indicates the velocity, and the relative phase indicates the direction, of the encoding wheel.
- 10 A typical input device includes at least two (one for each of two orthogonal directions of ball rotation), and often three encoding wheels, resulting in the use of four or six PTRs, and a minimum of 2 or 3 LEDs. A microcontroller is employed to control and interpret the sampling of the PTRs and to provide communication with a host device.
- 15 Some optical encoding methods require sample times of 50-100 $\mu$ s or more. Many traditional opto-mechanical encoding systems, while reliable and low-cost, may require as much as a 3-4mA average, and 10mA peak, current. Minimizing this current draw provides an important advantage in battery-operated or parasitically powered devices. Long sampling intervals
- 20 tend to result in higher average current than short sampling intervals. Long sampling intervals also limit the tracking performance. Shorter intervals allow higher-resolution tracking, or higher-speed tracking without aliasing, or both.

#### SUMMARY OF THE INVENTION

- 25 According to the present invention, a PTR in an optical encoding system is driven or "turned on," for sampling, by the application of a potential difference across its collector and emitter. A driving signal for producing the

potential difference the may be supplied, for example, from an output pin of an optical encoding system microcontroller.

An LED associated with the phototransistor may be excited with a low, continuous current. Prior to sampling the PTR, the collector and emitter  
5 are held at the same or nearly the same potential. Light from the LED reaching the PTR creates an excess of charge in the electrically isolated base of the PTR. As long as the potential between the emitter and collector of the phototransistor remains zero, transistor action cannot occur. Upon switching the voltage at the collector and/or emitter such that the collector/base junction  
10 is back biased and the base/emitter junction is forward biased, electrons can flow, transistor action can occur, and the PTR creates a large and very rapid current flow, in effect causing nearly instantaneous PTR response. For PTRs arranged for sampling of the emitter response, this virtually eliminates the effects of the collector/base capacitance on the emitter response time. Since  
15 the current developed by the PTR is proportional to the amount of light received by the PTR, the net effect is that the initial rising edge of the emitter output reaches a voltage level proportional to the modulation level of the encoder wheel, with a subsequent decay.

With the present invention, LED current may be set to a relatively  
20 low value, such as 1 to 1.5mA or even lower, resulting in the advantage of some power savings. The LED may also have a reduced duty cycle, for further power savings.

In applications where high performance is required, the fast emitter response can allow very high sampling rates, in excess of 5 kHz if desired, thus  
25 enabling realization of high performance systems with greater tracking velocity and/or higher resolution than most current designs.

Additional features and advantages of the invention will be made apparent from the following detailed description of an illustrated embodiment, which proceeds with reference to the accompanying drawings.

5

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of an embodiment of a system of the present invention.

FIG. 2 is a graph of an example input signal to a phototransistor as may be used in the present invention, together with output signals obtained 10 with such input signal.

FIG. 3 is a diagram of a phototransistor with its various control or input/output points labeled for reference.

FIG. 4 is a graph showing multiple output signals from a phototransistor employed to sample a function F.

15

### DETAILED DESCRIPTION OF THE INVENTION

An example embodiment of an apparatus of the present invention is shown in FIG. 1. An LED (light emitting diode) 20 is positioned near a PTR (phototransistor) 22 having a collector 23, an emitter 24, and a base 25 for receiving light from the LED 20. (A pair of phototransistors is normally used together, and an emitter 27 of a second phototransistor is shown accordingly.)

Between the LED 20 and the PTR 22 is a moveable optical encoder in the form of a rotatable optical encoding wheel 21 having alternating light-transmitting and light-blocking regions. Other suitable encoders may of course be potentially substituted, in locations appropriate to their type, including encoders having lateral rather than rotational motion, and encoders having alternating light and dark, or alternating reflective and non-reflective surfaces.

The light flux at the base 25 varies periodically as a function of the position of the encoder wheel 21. A microcontroller 26 samples the output of the emitter 24 on input/output line 28. The LED 20 is, in this embodiment, constantly turned on, but the PTR 22, in contrast, is turned on at its collector 23 by an output pin 30 of the microcontroller 26. The collector 23 is turned on, or driven high, just prior to sampling the output of emitter 24 via line 28.

Of course it is not essential that the PTR 22 be turned on at its collector 23. All that is required is that the potential difference across collector 23 and emitter 24 is switched from at or near zero (i.e., from a state at which little or no transistor action occurs) to a potential difference such that the collector/base junction is back biased and the base/emitter junction is forward biased. This effectively turns the PTR 22 on.

Turning on the PTR by switching the collector/emitter potential, (instead of by switching the LED, for instance) results in the output of the PTR occurring essentially instantaneously, not at the rate of the RC time constant of the PTR emitter circuit. In the described embodiment, emitter rise time is essentially identical to collector rise time, offset by a propagation delay of 10-20ns. If the collector driving waveform has a fast rise time in the range of about 10-20ns, the initial, peak emitter response is for all practical purposes instantaneous.

FIG. 2 is a graph representing actual response waveforms. Trace C is a waveform used to drive the collector, as may be produced by an output pin of a microprocessor. Trace A is the output waveform at the emitter when the light flux at the base is at a minimum and the collector is driven by the pulse in trace C. Trace B is the output waveform at the emitter when the light flux at the base is at a maximum and the collector is driven by the pulse in trace C. As may be seen from trace B, the response of the emitter is essentially instantaneous, with a rise time to peak response essentially equal to the rise

time of the sampling pulse in trace C, but offset by a small propagation delay on the order of 10-20ns. As shown, the rise time may be as short as 100ns or less, even as short as 10-20ns. The very short rise time allows quick sampling of the output signal without any prolonged wait for the signal to settle to the proper level.

FIG. 3 shows a PTR with four control or input/output points labeled G through J. First the associated LED or other light source is turned on (if not already on) to provide light input at point G. The light need only be turned on sufficiently long before the sampling of the PTR so as to produce the desired near-instantaneous response on sampling the PTR. The PTR is then sampled by imposing a potential difference across points H and J, and reading the voltage at point I. The potential difference may be imposed in any number of ways. For example, Point J may be held high, then switched low. Point H may be held low, then switched high. Point I may be held high, then switched to input mode and allowed to float to read the output signal voltage.

This method of sampling a phototransistor may be applied in similar fashion to transistors other than phototransistors. For example, in the case of a transistor other than a phototransistor, the light input at point G of FIG. 3 would be replaced by a signal line connected to the base of the PTR. A signal provided by such a signal line at point G may be sampled by allowing the signal to pre-charge the base of the PTR while the potential difference across the base and emitter of the PTR is maintained at or near zero. Upon application of a potential difference across the base and emitter of the PTR, a resulting output of the transistor may then be sampled as a voltage level at point I, or in any of various other ways known to those of skill in the art.

FIG. 4 is a graph of a function F similar to an output function that may produced at the output of one PTR by the rotation of an encoding wheel in the present invention. Multiple samples S of the PTR output assist in detecting

of the relative position and motion of the encoding wheel. Each sample S corresponds to a waveform such as those shown in trace A and trace B of FIG. 2, but with the time axis significantly compressed.

- It will be recognized that the illustrated embodiment can be modified  
5 by those of skill in the art without departing from the principles of the invention.  
When the potential difference is applied across the base and emitter of the  
transistor, the resulting performance of the transistor may be read or sampled  
in various ways, such as at the collector rather than at the emitter, and with  
various circuits or circuit elements known and used for such purposes by those  
10 of skill in the art. The basic process of sampling a transistor by first allowing  
charge to accumulate at the base thereof, and only then applying a potential  
difference across the collector and emitter, can also find application in any  
situation where fast response times or sharp-edged, easily detected responses  
are desirable.
- 15 In view of the many possible embodiments to which the principles of  
our invention may be applied, it should be recognized that the detailed  
embodiments are illustrative only and should not be taken as limiting the scope  
of the invention. Rather, we claim as our invention all such embodiments as  
may come within the scope and spirit of the following claims and equivalents  
20 thereto.

**CLAIMS**

We Claim:

1. An input device including an opto-mechanical encoding system  
5 comprising:
  - a light source;
  - a phototransistor having a collector, an emitter, and a base arranged to receive light from the light source to charge the base;
  - a moveable encoder structure structured so as to vary, periodically
- 10 with motion of the encoder structure, light flux at the base of the phototransistor;
  - a microcontroller for sampling the phototransistor and controlling the input device, the microcontroller programmed to turn on the phototransistor, when the light source is on and before sampling the phototransistor, by causing
- 15 a potential difference across the collector and emitter of the transistor to go from zero or near zero to a state in which the collector/base junction is back biased and the base/emitter junction is forward biased, so as to provide essentially immediate peak response from the phototransistor.
- 20 2. The input device of claim 1 wherein the light source is an LED.
3. The input device of claim 2 wherein the LED is connected to a voltage source so as to be constantly turned on.
- 25 4. The input device of claim 3 wherein the LED current is about 2mA or less.

5. The input device of claim 1 wherein the microcontroller is connected to the emitter of the phototransistor for sampling the phototransistor.

6. The input device of claim 1 wherein the time from causing the  
5 potential difference to the occurrence of the emitter peak response is less than 100ns.

7. The input device of claim 1 wherein the microcontroller is programmed to turn on the phototransistor by switching the collector from low  
10 to high.

8. The input device of claim 1 wherein the microcontroller is programmed to turn on the phototransistor by switching the emitter from high to low or to a floating voltage level.  
15

9. An optical encoder circuit comprising:  
a phototransistor having a collector, a base, and an emitter, the base being exposed to a variable light flux, the phototransistor being so arranged within the circuit as to provide for sampling of its response; and  
20 a signal source arranged to provide a signal to selectively turn on the phototransistor by causing application of a potential difference across the collector and emitter of the phototransistor for a collector on-time, and by causing application of no or little potential difference across the collector and emitter of the phototransistor for a collector off-time, wherein the off-time and  
25 the on-time, and the speed of transition from off to on of the signal source, are such as to produce, within 100ns after turning the phototransistor on, a peak phototransistor response for sampling, the response representative of a then-present level of light flux at the base.

10. The optical encoder circuit of claim 9 wherein the phototransistor is so arranged within the circuit as to provide for sampling of its response by sampling of a signal at its emitter.

5

11. A method of sampling a phototransistor having a base exposed to a light flux, a collector, and an emitter, the method comprising the steps of:

10 (a) leaving the collector and emitter at substantially equal potential for a phototransistor off-time during at least a last part of which the base is exposed to the light flux;

(b) applying a potential difference across the collector and the emitter, for a phototransistor on-time, so as to produce an transistor response having a substantially immediate peak followed by a decay; and

(c) sampling a response of the transistor.

15

12. The method of claim 11 further comprising the steps of providing light from an LED and providing a moveable encoder structure for varying the light flux at the phototransistor base from the LED with the position of the moveable encoder structure.

20

13. The method of claim 12 further comprising the step of powering the LED with a current of about 2mA or less.

25 14. The method of claim 12 wherein the step of applying a potential difference across the collector and the emitter comprises increasing the positive potential of the collector.

15. The method of claim 12 wherein the step of applying a potential difference across the collector and the emitter comprises allowing the positive potential of the emitter to decrease.

16. The method of claim 11 wherein the step of sampling a response  
5 of the transistor comprises sampling a response of the emitter.

17. A method of sampling a phototransistor in a computer input device having a microcontroller and a light source, the phototransistor having a collector, a base, and an emitter, the collector being connected to an output pin  
10 of the microcontroller, the method comprising the steps of:

(a) setting the output pin low while allowing the light source to charge the base of the phototransistor; and

(b) setting the output pin high and sampling the emitter of the phototransistor.

15

18. The method of claim 17 wherein the step of setting the output pin high drives the collector of the phototransistor high with sufficient speed to cause the emitter to respond with an immediate peak followed by a decay.

20

1/3

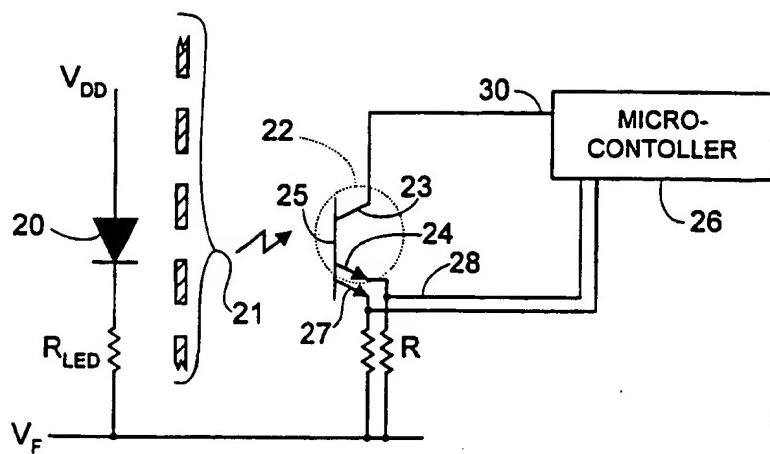


FIG. 1

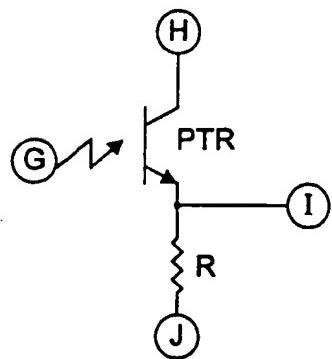


FIG. 3

2/3

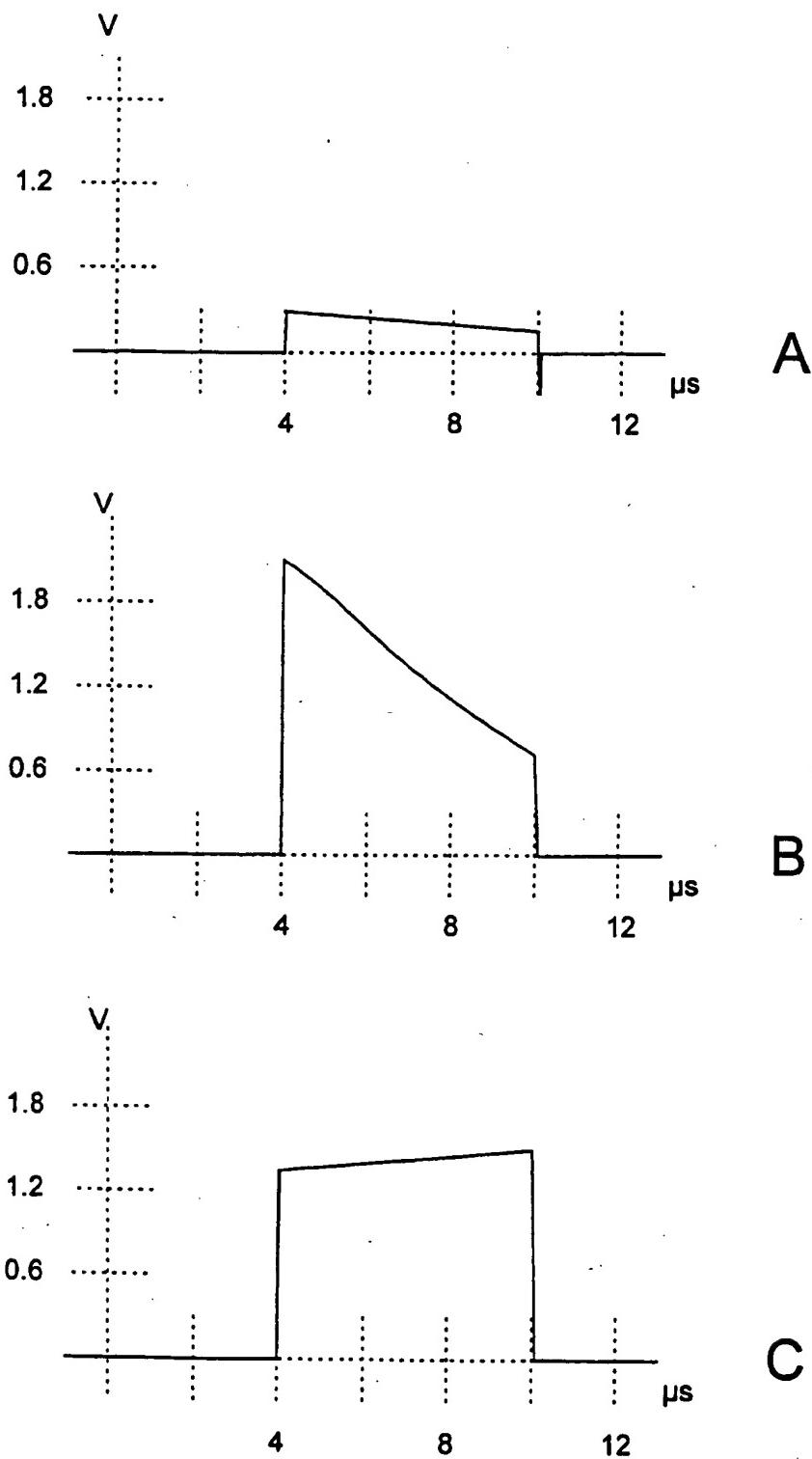


FIG. 2

3/3

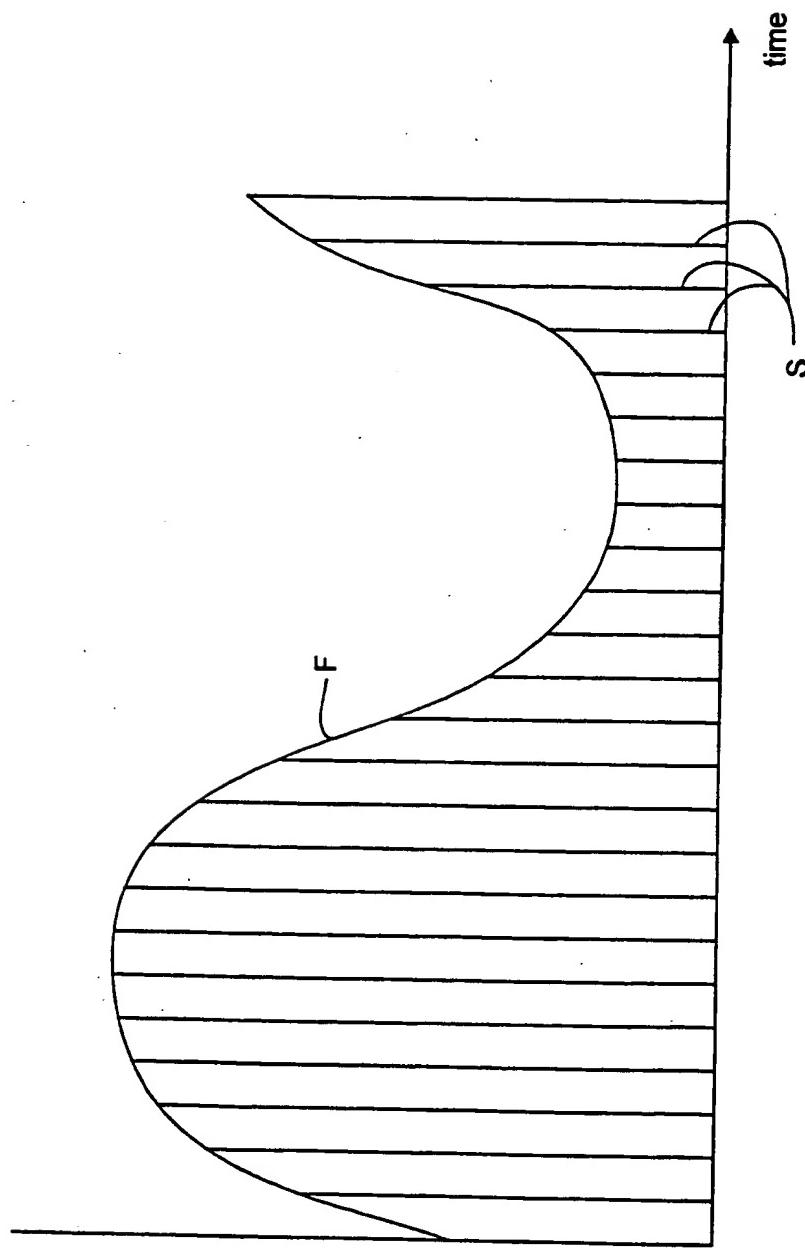


FIG. 4

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 99/28129

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 G06K11/18 H03K17/795

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G06K H03K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 252 968 A (DONOVAN PAUL M) 12 October 1993 (1993-10-12)  column 2, line 63 -column 3, line 46 figures 1,2	1-3,5,7, 11,12, 14,16,17
A		4,6,7,9, 13,15,18
X	EP 0 310 230 A (LOGITECH SA ;LOGITECH INC (US)) 5 April 1989 (1989-04-05)  column 1, line 2-35 column 4, line 1 -column 7, line 4 column 8, line 13 -column 12, line 14 figures 1-7	1-3,5,8, 11,12, 15,16
A		4,6,7,9, 13,14,17

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the International filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the International filing date but later than the priority date claimed

"T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the International search report
9 May 2000	16/05/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer  Baldan, M

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 99/28129

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 5252968	A 12-10-1993	AU	624508 B	11-06-1992
		AU	5578990 A	29-11-1990
		CA	2017486 A	24-11-1990
		DE	4015913 A	29-11-1990
		GB	2233086 A,B	02-01-1991
		JP	3102215 A	26-04-1991
EP 0310230	A 05-04-1989	AU	1025395 A	30-03-1995
		AU	657948 B	30-03-1995
		AU	1290092 A	18-06-1992
		AU	2049588 A	09-02-1989
		JP	1164076 A	28-06-1989
		US	5256913 A	26-10-1993
		US	5384457 A	24-01-1995